Evaluation of the Potential for Using Dry Rather Than Semi-Moist Food for Culturing Coho Salmon in British Columbia Hatchery Facilities. 2. Quinsam Hatchery 1977 Brood

J. R. Markert, D. A. Higgs, D. MacQuarrie, J. R. McBride, B. S. Dosanjh, J. Van Tine, and R. Reinhardt

Department of Fisheries and Oceans
Fisheries Research Branch
West Vancouver Laboratory
4160 Marine Drive
West Vancouver, British Columbia V7V 1N6

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Canadian Technical Report of

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EVALUATION OF THE POTENTIAL FOR USING DRY RATHER THAN SEMI-MOIST FOOD FOR CULTURING COHO SALMON IN BRITISH COLUMBIA HATCHERY FACILITIES

2. QUINSAM HATCHERY 1977 BROOD

March 1984

By

J. R. Markert[1], D. A. Higgs[1], D. MacQuarrie[2], J. R. McBride[1], B. S. Dosanjh[1], J. Van Tine[3], and R. Reinhardt[3]

[1]Department of Fisheries and Oceans
Fisheries Research Branch
West Vancouver Laboratory
4160 Marine Drive
West Vancouver, British Columbia V7V 1N6 Canada

[2]Department of Fisheries and Oceans
Enhancement Services Branch
Community Development Unit
1090 West Pender Street
Vancouver, British Columbia V6E 2P1

[3]Department of Fisheries and Oceans
Enhancement Services Branch
Quinsam River Salmon Hatchery
Box 467, Campbell River
British Columbia V9W 5C1

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ABSTRACT

Markert, J. R., D. A. Higgs, D. MacQuarrie, J. R. McBride, B. S. Dosanjh, J. Vantine, and R. Reinhart. 1984. Evaluation of the potential for using dry rather than semi-moist foods for culturing coho salmon in British Columbia hatchery facilities. 2. Quinsam Hatchery 1977 brood. Can. Tech. Rep. Fish. Aquat. Sci. No. 1260: v + 37 p.

To assess the potential for using dry diets (≤10% moisture) rather than Oregon moist pellets (OMP; 30% moisture) for coho salmon culture in B.C. hatcheries, juvenile coho salmon of about 2.4 g initial wet weight were fed one of two West Vancouver Laboratory dry diets (WV diets) or OMP at one of two ration levels for 301 days. The WV diets contained 25 (WV1) or 50 (WV2)% of dietary protein from a mixture of poultry-by-product meal and feather meal by replacement of herring meal. All diets had similar protein and metabolizable energy contents. Ration level was either 80 (WV1, WV2, OMP 80) or 65 (OMP 65) percent of the recommended daily caloric intake for maximum growth. Water temperatures varied between 7.8 and 11.6°C and all fish were maintained on a natural photoperiod.

All groups showed the same seasonal growth pattern, namely, rapid growth in summer and fall, slow growth between the fall equinox and winter solstice, and improved growth thereafter until release. Food and protein utilization followed a similar trend. Before release, all fish fed WV1, WV2 and OMP 80 were of similar size as a consequence of equivalent food and protein utilization during each of the three growth periods. Levels (%) of body proximate constituents were generally each within the ranges noted for OMP groups. Relative to wild coho smolts, cultured fish had depressed moisture, protein, and ash and increased lipid content. Hepatic and omentum lipid deposition was low (OMP 65) or high (WV1, WV2, OMP 80) in cultured fish and almost absent in wild smolts. Observed overall fish mortality was negligible in all groups whereas unaccountable or unexplained mortality was as high as 29.8%. The histological structure of a number of selected organs was normal, but furunculosis incidence (≤8.3%) was detected in WV1; WV2 and OMP 65 groups. All groups had excellent osmoregulatory ability before seawater entry.

Percent returns to the commercial fishery and hatchery were similar for all groups but owing to the higher returns of test OMP groups to the recreational fishery, total percent returns for the latter groups were increased. Production fish fed OMP, however, had slightly poorer marine survival than WV groups.

It is concluded that there is high potential for using dry diets in coho salmon culture provided that the available levels and balance of nutrients in dry diets are similar to those in OMP and good diet manufacturing practices are employed.

Key words: diets, dry, moist, coho, Oncorhychus kisutch, survival, growth, protein source.

RÉSUMÉ

Markert, J. R., D. A. Higgs, D. MacQuarrie, J. R. McBride, B. S. Dosanjh, J. Vantine, and R. Reinhart. 1984. Evaluation of the potential for using dry rather than semi-moist foods for culturing coho salmon in British Columbia hatchery facilities. 2. Quinsam Hatchery 1977 brood. Can. Tech. Rep. Fish. Aquat. Sci. 1260: v + 37 p.

Dans le but d'évaluer la possibilité de subtituer des aliments secs (≤10 % humidité) à des boulettes humides Oregon (OMP; 30 % humidité) pour l'élevage du saumon coho dans les piscifactures de la Colombie-Britiannique, on a nourri des cohos juvéniles pesant environ 2.4 g (poids humide initial) avec deux types d'aliments secs du laboratoire de Vancouver-Ouest (régime VO) ou des OMP à deux différentes teneurs pendant 301 jours. Les régimes VO contenaient 25 % (VO1) ou 50 % (VO2) de protéines alimentaires obtenues d'un mélange de farine de sous-produits de la volaille et de farine de plumes en remplacement de farine de hareng. Tous les régimes avaient le même contenu en protéines et en énergie métabolisable. Le niveau d'alimentation était soit de 80 % (VO1, VO2, OMP 80) ou de 65 % (OMP 65) de l'absorption calorique quotidienne recommandée pour une croissance maximum. Les températures de l'eau variaient entre 7.8 et 11.6° C, et une photopériode naturelle était maintenue pendant toutes les expériences.

Tous les groupes ont suivi le même schème de croissance saisonnière c'est-à-dire une croissance rapide en été et en automne, une croissance ralentie entre l'équinoxe d'automne et le solstice d'hiver et une croissance améliorée après cette période et jusqu'à la mise en liberté. La consommation de nourriture et de protéines était semblable. Avant le lâcher, tous les poissons nourris de VO1, VO2 et d'OMP 80 mesuraient presque la même longueur par suite d'une utilisation équivalente des aliments et des protéines pendant les trois périodes de croissance. Les niveaux (%) des composants corporels immédiats étaient généralement dans les limites des gammes notées pour les groupes OMP. La teneur en humidité, en protéines et en cendre était moins élevée chez les poissons domestiques que chez les saumoneaux sauvages tandis que le contenu en lipides était supérieur. Le dépôt de lipides hépatiques et épiploïques était faible (OMP 65) ou élevé (VO1, VO2, OMP 80) chez les poissons d'élevage et presque absent chez les cohos sauvages. La mortalité totale observée était négligeable dans tous les groupes tandis que la mortalité totale observée était négligeable dans tous les groupes tandis que la mortalité inexpliquée ou inexplicable atteignait jusqu'à 29.8 %. Un certain nombre d'organes choisis était normal au niveau histologique, mais on a détecté l'incidence de furonculose (≤8.3 %) chez les groupes VO1, VO2 et OMP 65. Tous les groupes démontraient une excellente capacité osmorégulatoire avant l'entrée en eau salée.

Le pourcentage de poissons capturés par les pêcheurs commerciaux et revenus à la piscifacture était semblable pour tous les groupes mais, à cause des captures plus élevées des poissons du groupe OMP par les pêcheurs sportifs, le pourcentage total des prises de ce dernier groupe était plus élevé. Les poissons domestiques nourris d'OMP ont toutefois accusé une plus faible survie en mer que les groupes VO.

Les auteurs tirent la conclusion qu'il existe un potentiel élevé pour l'utilisation d'aliments secs dans l'élevage du saumon coho à condition que les niveaux et l'équilibre des bioéléments soient semblables à ceux des OMP et que de bonnes méthodes de fabrication des aliments soient utilisées.

Mots-clés: régime, sec, humide, coho, Oncorhynchus kisutch, survie, croissance, source de protéine

INTRODUCTION

This study was undertaken to assess the potential for using dry diets rather than Oregon moist pellets (OMP) for culturing coho salmon in British Columbia (B.C.) hatchery facilities. Dry diets (≤10% moisture) are less expensive to manufacture, transport and store and are easier to dispense through automatic feeders than their moist (~ 30% moisture) counterparts. These were deemed to be important considerations when assessing possible alternatives to OMP because coho salmon have a long freshwater residency period (14-16 months). Moreover, food costs presently account for 25-40% of fish culture expense (Van Tine, pers. comm.; Tiews et al. 1976; Vondruska 1980). The selection of ingredients for the test dry diets developed at the West Vancouver Laboratory was on the basis of nutritive value, local availability and cost. In this regard, one of the diets was formulated to assess whether 50% of the dietary protein could be supplied by protein from a mixture of poultry-by-product meal and feather meal without compromising growth and survival. When this study was initiated fish meal in B.C. was highly variable in quality due to flame drying during processing and marked differences in salt content as a consequence of harvesting herring for their roe. Laboratory tests (Higgs et al. 1979) showed that poultry-by-product meal alone or blended with feather meal could decrease reliance on expensive fish meal to furnish most of the dietary protein. However, this required confirmation on a production scale. All diets employed in this study had high levels of protein and lipid to optimize juvenile coho salmon food conversion efficiency at the temperatures encountered at Quinsam River Salmon Hatchery (Clarke et al. 1982).

MATERIALS AND METHODS

EXPERIMENTAL CONDITIONS AND DIETS

On May 31 and June 1 1978, coho salmon swim-up fry, the progeny of Quinsam River B.C. stock, were randomly distributed among four Burrows ponds (Burrows and Chenoweth 1970) so that each contained about 100,000 fish. Aerated groundwater was supplied to each 24.6 m x 5.6 m x 3 m pond at a rate of 400 to 600 gallons per minute depending upon fish biomass. During the study a natural photoperiod was in effect and water temperature ranged between 8 and 11.7°C (Fig. 1).

Before initiation of test feeding, all fish were fed daily with OMP (Table 1) manufactured by Moore Clarke Co., Laconner Washington U.S.A. in accordance with the recommended OMP feeding schedule (near satiation). However, after July 7, 1978 (day 0) when the average fish size was about 2.4 g, each group was maintained on one of four dietary treatments. Two groups continued to receive OMP but the level of dietary intake of one group was adjusted to 65% and the other to 80% of the recommended daily ration.

This enabled a determination of whether the imposed difference in plane of nutrition would significantly affect the incidence of infectious disease, smolt size and body composition at the time of ocean release, and possibly marine survival. Moreover, the OMP ration level was varied to ensure that possible differences in smolt size at time of release would not be a confounding variable when assessing the returns of adults formerly fed diets of different composition during freshwater culture. The two remaining groups were fed either the West Van 1 (WV1) or West Van 2 (WV2) experimental dry diets (Table 2) for reasons mentioned previously. Both diets were manufactured at Ritchie Smith Ltd, Abbotsford, B.C. about every 12 weeks and they had similar protein and metabolizable energy content relative to OMP (Table 3). The change from OMP to the respective experimental dry diets (E) was accomplished in three successive 3-day intervals as follows: 3/4 OMP:1/4 E; 1/2 OMP:1/2 E; 1/4 OMP:3/4 E. The prescribed ration for coho fed the dry diets was indentical to that of coho fed OMP at the 80% level on a gross caloric basis i.e., equivalent gross caloric intake/g wet body weight. Estimates of actual rations consumed by the fish in each group during the study are provided in Table 4. The respective daily rations were dispensed by automatic feeders every 20 to 30 minutes from dawn to dusk. Diet particle size was adjusted in relation to fish size (OMP feeding chart; Fowler and Burrows 1971) and each diet was kept frozen throughout the study. Interruption of the experimental protocol occurred briefly in September 1978 when the feeding of WV diets was suspended due to detection of extensive lipid peroxidation. This stemmed from inclusion of improperly stabilized marine oil at the time of diet manufacture. The situation was corrected rapidly and treatments were resumed.

GROWTH, FOOD AND PROTEIN UTILIZATION, FISH HEALTH, BODY COMPOSITION, OSMOREGULATORY ABILITY AND MARINE SURVIVAL

To evaluate the influence of dietary treatment on growth, 150 fish were randomly selected from each group at approximately 28-day intervals and were individually weighed and measured (Markert et al. 197?, unpublished). Records of daily food intake and mortality for each group were maintained for subsequent use in the calculation of food and protein utilization and percent mortality. Representative samples of fish were removed from each group at several times during the study (Table 7) for assessment of fish health and at the end of the study for evaluation of the histological structure of selected organs (Table 9) according to the methods given by Higgs et al. (1979; 1982).

Whole body proximate compositions of cultured fish on day 83, 164 and 300 and of wild coho smolts captured at the Quinsam River fence on their downstream migration during the week of May 1-8, 1979 were carried out according to the methods of Higgs et al. (1979). Diets were analyzed using similar procedures.

Prior to ocean release, the osmoregulatory ability of fish in each group was assessed using the procedure of Clarke and Blackburn (1977). To evaluate ocean survival, about 25,000 coho were removed from each group (Table 11) in November, 1978. All fish were marked by removing the adipose fin, differentially tagged by inserting a coded wire tag into the snout (Jefferts et al. 1963) and then returned to their respective ponds. The fish

were simultaneously released into the Quinsam River on the evening of May 4, 1979.

DATA ANALYSIS

On the basis of the growth pattern observed in all groups (Fig. 1) the experiment was divided into three stanzas for data analysis. Stanzas I, II and III corresponded to day 0 to 83, day 84 to 223, and day 224 to 300, respectively.

Mean wet and dry weights and condition factors which relate fork length to body weight (Vanstone and Markert 1968) were computed for each group at each growth measurement time (Table 4). However, for clarity, values are shown only for the beginning and end of each growth stanza.

Specific growth rates (Brett 1979), food conversion (wet weight gain (g) ÷ dry food intake (g)), food conversion efficiency (dry weight gain x 100 ÷ dry food intake (g), protein efficiency ratio (wet or dry weight gain (g) ÷ protein intake (g)) and protein utilization (protein gain (g) x 100 ÷ protein intake (g)) were computed for each stanza. Moreover, food conversion, food conversion efficiency and protein efficiency ratio were calculated for each interval within each stanza. Unfortunately, 0 time samples for body composition were lost and therefore estimates of initial dry matter and protein content of the fish were based on extrapolated values. This may have influenced the accuracy of some of the foregoing parameters in stanza I. However, the situation was deemed not to be serious since there was good agreement in trends for food conversion and food conversion efficiency, protein efficiency ratio on a wet or dry basis, and between protein efficiency ratio and protein utilization in Stanza I (Figs. 3 and 4).

The data were subjected to various types of Analyses of Variance (ANOVA, see individual tables and figures) and when appropriate to Newman Keuls test or Scheffé's test (growth rates only) with $P = 0.05$ to detect significant differences between treatment means. The standard error of the mean was derived by using the appropriate error mean square from the ANOVA as the estimate of sample variance.

RESULTS AND DISCUSSION

1. EFFICACY OF DIET TREATMENTS DURING FRESHWATER CULTURE

Growth and Condition Factor

Differences between diets in their composition, moisture content and caloric intake did not exert a major influence on growth in this study (Tables 5 and 6). Final sizes and growth rates of coho fed WV1, WV2, and OMP

at the same level of dietary intake were not significantly different. Poston (1974), Bromley (1980), Bromley and Smart (1981), Higgs et al. (1983) and Markert et al. (1982, unpublished) also found that dietary moisture content did not significantly influence fish growth provided that the available dietary nutrient levels were similar. In this regard, our results showed that 50% of the protein in coho salmon diets may originate from a combination of poultry-by-product meal and feather meal without impairment of growth. Other studies on salmon and trout have also shown that fish meal protein can be replaced partially or entirely by protein from a mixture of poultry-by-product meal and feather meal without loss of performance (Tiews et al. 1976, Higgs et al. 1979, Fowler 1981). Mean weights of coho fed OMP at two ration levels were not significantly different at the end of Stanza II (day 223). However, by day 300 ration restriction did depress mean weight significantly (Tables 5 and 6).

All groups displayed the same seasonal pattern of growth (Fig. 1) which was characterized by rapid growth between midsummer (start of study) and the fall equinox, slow growth between the fall equinox and winter solstice and resumption of increased growth shortly after the winter solstice. Vanstone and Markert (1968) and Fagerlund et al. (1983) observed a similar seasonal growth pattern in juvenile coho, which as the latter authors explained, probably reflects changes in endogenous hormonal milieu directed predominately by photoperiod. Our findings are consistent with this view point since water temperature in this study varied over a narrow range.

Figure 2 illustrates the monthly changes in condition factor that were observed in all groups during the study. Regardless of diet treatment, all groups initially grew more rapidly in weight than in length. Subsequently, condition factors declined at first slowly and then rapidly during smoltification. It is noteworthy that the decline in condition factor of WV groups during Stanza II was more rapid than noted for fish fed OMP. Vanstone and Markert (1968) also observed similar changes in the condition factor of juvenile coho before entry into the ocean. By day 300, the body forms of coho fed WV2 and OMP (80%) were not significantly different whereas coho fed WV1 were comparatively more slender in shape (Table 7). Coho fed OMP at two ration levels had almost identical mean condition factors on day 300.

Food and Protein Utilization

Dietary treatment did not significantly influence the capacity of fish to convert food into flesh or their ability to utilize protein for growth or for synthesis of body protein (Figs. 3 and 4). As a general trend, food and protein utilization were highest during Stanza I and lowest during Stanza II; the periods of rapid and slow growth, respectively. Restriction of OMP ration during Stanza I did improve food and protein conversion but again not significantly.

Body Composition

Significant differences in body composition were not observed on day 83. This was also true for body moisture, ash, and protein contents of the groups on day 164. Lipid contents of WV groups were, however,

significantly lower than noted in fish fed OMP at this time. Terminal body moisture and ash contents (Fig. 5) were not significantly affected by dietary treatment. However, lipid and protein contents in coho fed OMP at the 80% level were respectively higher and lower than in fish fed WV diets. This was probably a consequence of the high lipid content or low protein to lipid ratio in OMP (Table 3; Reinitz and Hitzel 1980, Clarke et al. 1982, Fagerlund et al. 1983). Reduction in the feeding level of OMP lowered carcass lipid content to that noted in fish fed WV1. By contrast body protein content was increased in fish fed OMP at 65% of recommended ration to levels measured in fish fed WV diets. Fish fed WV2 had significantly lower body lipid content relative to those fed WV1 probably because the ratios of protein to lipid and of digestible protein to digestible energy were higher in the former diet than in the latter (Table 3).

Wild coho smolts had increased moisture and protein content and dramatically decreased lipid content relative to cultured counterparts (Fig. 5). Moreover, hepatic and omentum lipid deposition (Table 9; Fig. 6) was negligible in wild smolts, low in fish fed OMP at 65%, and extensive in WV groups and in fish fed OMP at 80%. Differences in ration level, in food composition, in level of physical activity and in fish size mainly account for the dissimilar proximate compositions of wild and cultured coho. Further, it is presently not known whether body composition of coho smolts is an important factor in determining return rate independent of an effect of size and time of release (this topic is reviewed by Ludwig 1982 and Plotnikoff et al. 1983a,b).

Fish Health and Mortality

Mean hematocrits (Table 7) in all cases during Stanzas II and III were equivalent to or exceeded 38%. Prior to release, no evidence of pathology was found in the histological structure of the liver, kidney, pancreas, alimentary tract, interrenal, gonad, thyroid and pituitary (Table 9). However, furunculosis was detected in WV groups and in fish fed OMP at the 65% level. Highest incidence of this infectious disease was noted in fish fed WV2. No evidence of bacterial kidney disease was found. In Stanzas I and II, the observed mortalities in the groups were insignificant relative to the unaccountable mortalities (Table 8). High unaccountable mortality may have been due to errors in the initial allocation of the fish to the ponds, cannibalism, bird predation, losses of small fish down drains or a combination of these factors. Overall observed mortalities were higher in WV groups than in OMP-fed fish but were still negligible and did not exceed 2.2% of the estimated initial number of fish in each of the groups (Table 8).

Osmoregulatory Performance

No significant differences were found in the osmoregulatory ability of the groups before entry into the ocean. Mean plasma sodium titres did not exceed 161 meq/l, (Table 10). Coho smolts with plasma sodium concentrations below 170 meq/l, and especially in the range of 150 to 160 meq/l, would be predicted on the basis of findings presented by Clarke and Blackburn (1977) and Wedemeyer et al. (1980) to have excellent ability to grow and develop normally in the marine environment.

2. INFLUENCE OF DIETARY TREATMENT ON MARINE SURVIVAL

Table 11 illustrates the estimated returns of 2-, 3- and 4-year-old coho to the commercial and recreational fisheries and to Quinsam hatchery in relation to dietary treatment during freshwater culture. Return information for production coho which were reared in eleven Burrows ponds and fed OMP is also included for comparison. It should be mentioned at the outset that the sequence for reliability of return information is as follows: hatchery> commercial fishery > recreational fishery. Sport or recreational fishery data are highly unreliable because returns are not based on consistent random sampling efforts. In this study we assumed that 16.7% of the tagged sports fish caught would be recognized and reported (T. Perry, R. Reinhart personal communication). However, the awareness or expansion factor for sports data can vary greatly depending upon the time, area and season in which the fish are caught. The reader should refer to Bilton et al. (1982) for more complete information on this topic.

With the aforementioned limitations in mind, we observed that the totals of the percent returns to the commercial fishery and hatchery were similar for groups formerly fed WV diets and OMP at the same level of dietary intake. In the case of fish formerly fed OMP at the 65% level slight enhancement of return rate was noted. Production coho showed the poorest combined percent return.

Percent returns to the recreational fishery were equivalent for WV groups and production coho. However, percent returns of test OMP fish, irrespective of ration level during hatchery culture, were higher than noted for the other groups. Consequently, percent returns from all sources, were best for test OMP fish while those for WV groups were either similar to (WV1) or greater than (WV2) those observed for production coho.

The foregoing results clearly demonstrate the potential for use of dry diets in the hatchery culture of juvenile coho salmon since the percent returns of WV groups and of production coho were similar. The reason(s) for the poorer survival of fish fed WV diets relative to test fish fed OMP is not readily apparent. Several of the factors which have a demonstrated or strongly suspected role in affecting the marine survival of anadromous salmonids such as size and time of release (Bilton et al. 1982), body composition (Wood et al. 1957, Burrows 1969, Plotnikoff et al. 1983a,b), osmoregulatory ability (Clarke and Blackburn 1977) and disease prevalence (Wedemeyer et al. 1980) were either identical in all groups or were within the ranges noted in the two groups of fish fed OMP. However, this does not exclude the possibility that one or more of these variables did exert an influence. For example, it could be argued that furunculosis incidence was actually higher in WV groups before release than observed. Furunculosis incidence was based on examination of only 60 fish from each group. Further the observed mortalities of WV groups while low, were nevertheless consistantly higher than noted for OMP groups during Stanza III. Conversely, factors other than nutritional status i.e. water quality may have reduced the quality of WV smolts. Additional studies are required to resolve the situation.

In summary, our results show that coho salmon performance during

freshwater culture was not jeopardized by feeding less expensive dry diets despite the fact that the WV diets used in this study were not of the highest possible quality due to inexperience in the manufacturing sector.

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TABLE 1 - Composition of Oregon moist pellets (OMP-2).

Ingredients	g/kg diet as fed
Dry mix	
Fish meal	280-300
Cottonseed meal	170
Wheat germ meal	40
Dried whey product	50
Shrimp or crab meal	40
Corn distiller's dried solubles	20-40
Vitamin premix[a]	15
Wet mix	
Wet fish	300
Herring or soybean oil, antioxidant[b]	60
Choline chloride (liquid; 70% product)	5

[a] The vitamin supplement supplied the following levels of nutrients (mg/kg dry diet unless otherwise indicated): alpha tocopherylacetate 717 IU, menadione sodium bisulfite complex 25.7; pantothenic acid 151; B_6 25.2; riboflavin 75.5; niacin 269; folic acid 18.2; thiamine 33.7; biotin 0.85; B_{12} 85 µg; myo-inositol 378; vitamin C 1274.

[b] Stabilized with 0.3% BHA-BHT (1:1); soybean oil to be "fully refined"; herring oil to contain less than 5 ppm DDT or its analogs, less than 3% free fatty acids, and not to be alkaline reprocessed.

TABLE 2 - Composition of test diet formulations. Four separate batches of West Van 1 (WV1) and West Van 2 (WV2) were prepared during the 301-day study. Ranges for each dietary component are shown.

Ingredients (g/kg dry diet)	Diet	
	WV-1	WV-2
Flame-dried herring meal (C.P.[1] = 69.7-79.6%)	292.0 - 333.0	112.4 - 128.3
Poultry-by-product meal (C.P. = 64.3-73.5%)	100.0 - 115.0	215.6 - 246.7
Feather meal (C.P. = 89.9-90.2%)	56.4 - 56.6	120.9 - 121.5
Blood flour (C.P. = 91.2-96.0%)	49.6 - 52.2	49.6 - 52.2
Soybean meal (C.P. = 50.4-52.2%)	131.0 - 136.0	131.0 - 135.7
Shrimp meal (C.P. = 35.9-48.0%)	49.0 - 65.4	49.1 - 65.4
Wheat middlings (C.P. = 16.8-17.5%)	97.2 - 107.4	91.2 - 99.2
Vitamin-mineral supplement[2]	53.2	53.2
Herring or salmon oil + antioxidant	71.7 - 101.5	66.4 - 92.3
Soybean lecithin	9.3	9.3
Permapell (lignin sulphonate binder)	21.3	21.3
Kelp meal	6.0 - 6.2	6.0 - 6.2
DL-methionine	0 - 6.64	8.5 - 8.6
Calcium phosphate dibasic	-	10.6 - 15.0

[1] Crude protein

[2] The vitamin-trace mineral supplement supplied the following levels of nutrients/kg of dry diet: vitamin A acetate 7769 IU; cholecalciferol 518 IU; dl alpha tocopherylacetate 826 IU; MSBC 12.9 mg; D-calcium pantothenate 93.2 mg; pyridoxine HCl 51.8 mg; riboflavin 62.2 mg; niacin 647 mg; folic acid 10.4 mg; thiamine mononitrate 51.8 mg; biotin 0.52 mg; cyanocobalamin 26.0 µg; inositol 466 mg; choline chloride 1036 mg; ascorbic acid (ethocel coated; Hoffmann-LaRoche) 1108 mg; NaCl 5315 mg; Mn (as $MnSO_4.H_2O$) 73.4 mg; I (as KI) 3.46 mg; Fe (as Fe_2O_3) 21.3 mg; Cu (as $CuSO_4$) 3.48 mg; Zn (as ZnO) 1.07 mg; Co (as $CoCl_2.6H_2O$) 0.21 mg. The vitamin supplement supplied 118 mg of ethoxyquin/kg of diet.

[3] Marine oil was stabilized with 0.33% butylated hydroxyanisole-butylated hydroxy toluene (BHA-BHT) (1:1).

TABLE 3 - Proximate composition of diets fed to juvenile coho salmon over a 301-day period. Means ± 1 SEM (measured values only) are shown. Refer to Table 1 for additional information.

Proximate analysis (% of dry matter)	Diet		
	WV-1	WV-2	OMP
Protein (% N x 6.25)	50.3 ± 2.2	52.8 ± 1.2	47.3 ± 0.60
Crude lipid (Bligh-Dyer)	14.6 ± 0.58	14.2 ± 0.32	17.7 ± 0.53
Crude fiber[1]	5.4	5.6	3.64
Nitrogen-free extract (NFE)	19.6	17.5	17.8
Ash	10.1 ± 0.35	9.94 ± 0.16	13.6 ± 0.35
Moisture (as fed)	9.61 ± 0.85	9.08 ± 0.65	27.1 ± 0.25
Metabolizable energy (kcal/g)[2]	3.59	3.63	3.69
Digestible protein (mg/dig kcal)[3]	126	131	115
Protein/lipid	3.44	3.71	2.67

[1] Crude fiber content of the diets was estimated (NRC, 1981). Subsequently, NFE values were calculated.

[2] Brett and Groves (1979) coefficients used for estimating caloric value of the diets, i.e., 4.2 kcal/g crude protein; 8.0 kcal/g crude lipid and 1.6 kcal/g carbohydrate.

[3] Calculated assuming protein 90% digestible.

TABLE 4 - Estimated rations (dry food (g) ÷ wet body weight (g) x 100) consumed by juvenile coho salmon fed experimental diets or OMP. Prescribed rations were either 80 (WV1, WV2, OMP, 80) or 65% (OMP, 65) of those recommended in the Oregon moist pellet feeding chart on gross energy basis.

	Diet			
Day	WV1	WV2	OMP (80%)	OMP (65%)
1	2.31	2.50	1.92	2.18
28	1.91	1.96	1.90	1.58
56	1.85	1.51	1.71	1.40
83	1.47	1.59	1.35	1.14
112	1.14	1.02	1.24	1.15
143	0.84	0.66	0.92	0.66
164	0.81	0.63	0.85	0.69
195	1.22	1.21	1.06	1.04
223	0.97	1.15	1.17	0.95
251	0.58	0.51	0.52	0.43
278	0.47	0.45	0.45	0.42
300	0.49	0.49	0.53	0.38

TABLE 5 - Wet weights (geometric means with 2SE on either side of mean shown in parentheses) and growth rates of juvenile coho salmon fed experimental diets or OMP at two ration levels. Refer to Table 1 of text for additional information.

Parameter	Stanza	Day	Diet			
			WV1	WV2	OMP (80%)	OMP (65%)
Wet weight[1] (g)	1	0	2.49[a] (2.34- 2.64)	2.22[a] (2.10- 2.36)	2.37[a] (2.24- 2.52)	2.38[a] (2.24- 2.53)
	1	83	8.36[b] (7.82- 8.94)	7.15[a] (6.69- 7.64)	6.74[a] (6.30- 7.20)	8.47[b] (7.93- 9.06)
	2	223	15.1[b] (14.4 -15.9)	13.6[a] (13.0 -14.3)	14.8[b] (14.1 -15.6)	14.5[a,b] (13.8 -15.2)
	3	300	19.6[a,b] (18.8 -20.5)	19.4[a,b] (18.6 -20.3)	20.1[b] (19.2 -21.0)	18.5[a] (17.7 -19.4)
Growth rate[2] (% wet wt/day)	1	0-83	1.46[a,b] ±0.10	1.47[a,b] ±0.10	1.29[a] ±0.10	1.53[b] ±0.10
	2	84-223	0.318[a] ±0.058	0.287[a] ±0.058	0.375[a] ±0.058	0.355[a] ±0.058
	3	224-300	0.370[a] ±0.135	0.350[a] ±0.135	0.293[a] ±0.135	0.247[a] ±0.135

[1] One-way Analysis of variance (ANOVA) for each time indicated $P > 0.05$ for day 0 and 300, $P < 0.001$ for day 83 and $P < 0.05$ for day 223. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

[2] Analysis of covariance with equality of slope test across diets for $\log_e$ wet weights indicated $P < 0.01$ for stanza 1 and $P \geq 0.05$ for stanzas 2 and 3. Diet groups with the same superscript form a homogeneous subset (Scheffé's multiple range test with $P = 0.05$).

TABLE 6 - Dry weights (geometric means with 2SE on either side of mean shown in parentheses) and growth rates (mean ± 2SEM) for groups of juvenile coho salmon fed experimental diets or OMP at two ration levels. Refer to Table 1 for additional information.

Parameter	Stanza	Day	Diet			
			WV1	WV2	OMP (80%)	OMP (65%)
Dry weight[1] (g)	1	0	0.73^{b} (0.68-0.77)	0.64^{a} (0.60-0.67)	$0.67^{a,b}$ (0.63-0.71)	$0.69^{a,b}$ (0.65-0.73)
	1	83	2.28^{b} (2.14-2.44)	1.92^{a} (1.80-2.06)	1.79^{a} (1.67-1.91)	2.30^{b} (2.15-2.45)
	2	223	3.86^{b} (3.68-4.06)	3.52^{a} (3.36-3.70)	3.88^{b} (3.70-4.07)	3.77^{b} (3.59-3.96)
	3	300	$4.55^{a,b}$ (4.36-4.75)	$4.60^{a,b}$ (4.40-4.80)	4.79^{b} (4.58-5.00)	4.37^{a} (4.18-4.56)
Growth rate[2] (% dry wt/day)	1	0-83	$1.38^{a,b}$ ±0.10	$1.40^{a,b}$ ±0.10	1.22^{a} ±0.10	1.45^{b} ±0.10
	2	84-223	0.254^{a} ±0.058	0.241^{a} ±0.058	0.342^{a} ±0.058	0.306^{a} ±0.058
	3	224-300	0.244^{a} ±0.13	0.234^{a} ±0.13	0.170^{a} ±0.13	0.115^{a} ±0.13

[1] One-way ANOVA for each time indicated $P < 0.05$ for day 0, 223 and 300, and $P < 0.001$ for day 83. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

[2] Analysis of covariance with equality of slope test across diets for $\log_e$ dry weights indicated $P < 0.05$ for stanza 1 and $P > 0.05$ for stanzas 2 and 3. Diet groups with the same superscript form a homogeneous subset (Scheffé's multiple range test with $P = 0.05$).

TABLE 7 - Condition factors and hematocrits for groups of juvenile coho salmon fed experimental diets or OMP at two ration levels. Means and two standard errors of mean are shown. Also, numbers of fish examined for hematocrit are indicated in parentheses. Refer to Table 1 for additional information.

Parameter	Stanza	Day	Diet				
			WV1	WV2	OMP (80%)	OMP (65%)	2SEM
Condition[1] factor	1	0	6.96[a]	6.93[a]	7.08[a]	7.06[a]	0.097
	1	83	7.02[a]	7.02[a]	7.19[b]	7.07[a]	0.065
	2	223	6.28[b]	6.18[a]	6.54[c]	6.53[c]	0.058
	3	300	5.22[a]	5.46[c]	5.39[b,c]	5.33[b]	0.070
Hematocrit (%)	1	26	37.2(20)[c]	40.3(20)[d]	35.0(19)[b]	32.6(20)[a]	1.5
	2	117	40.3(20)[a]	40.6(20)[a]	38.2(19)[a]	39.5(20)[a]	1.4
	2	216	40.1(20)[a]	39.7(20)[a]	38.0(20)[a]	40.0(19)[a]	1.3
	3	257	43.6(20)[b]	44.4(20)[b]	40.2(20)[a]	42.0(20)[a,b]	1.8
	3	300	45.4(60)[a]	45.2(60)[a]	47.4(60)[b]	44.7(60)[a]	1.3

[1] Calculated as wet weight (g) x 1000 ÷ fork length (cm) $^{3.25}$. One-way ANOVA for each time indicated $P > 0.05$ for day 0, and $P < 0.001$ for days 83, 223 and 300. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

[2] One-way ANOVA indicated $P < 0.001$ for day 26, $P > 0.05$ for days 117 and 216, $P < 0.01$ for day 257 and $P < 0.05$ for day 300. Values with a common superscript were not significantly different (Newman Keuls test with $P = 0.05$).

TABLE 8 - Observed and unaccountable mortality of juvenile coho salmon for each growth stanza and over the 301-day experimental period. Mortality is expressed relative to the estimated number of fish at the beginning of each stanza (within) or to the estimated initial number of fish on day 0 (overall). Refer to Table 1 and Figure 1 for additional information.

Stanza	Day	Mortality (%)	Diet			
			WV1	WV2	OMP (80%)	OMP (65%)
1	0-83	observed	0.48	0.49	0.51	0.50
		unaccountable	15.0	6.17	13.2	13.0
2	84-223	observed	0.41	0.34[1]	0.32	0.37[2]
		unaccountable	17.4	6.49	15.0	13.5
3	224-301	observed	1.78	1.58	0.31	0.76
		unaccountable	0	0	0	0
1-3	0-301	observed	2.06	2.17	1.01	1.38
		unaccountable	29.8	12.2	26.2	24.7

[1] An additional 0.94% mortality was observed but this occurred at the time of marking and tagging.

[2] An additional 0.41% mortality was observed due to marking and tagging.

TABLE 9 - Fish health and histological assessments of juvenile coho salmon just before release from Quinsam hatchery. Ten representative fish from each diet treatment and ten wild coho smolts trapped in the immediate vicinity of Quinsam hatchery were examined histologically. Refer to Table 1 for additional information.

	Diet				Wild coho smolts
	WV1	WV2	OMP (80%)	OMP (65%)	
Disease evaluation					
Furunculosis incidence[1]	1/60	5/60	0/60	3/60	-
Bacterial kidney disease incidence	0/60	0/60	0/60	0/60	-
Histological assessment					
Liver[2]	HL	HL	HL	LL	VLL
Kidney	N[3]	N	N	N	N
Pancreas	N	N	N	N	N
Alimentary tract	N	N	N	N	N
Interrenal	N	N	N	N	N
Gonad[4]	LPS	LPS	LPS	LPS	N
Thyroid[5]	N	N	N	N	N
Pituitary[6]	N	N	N	N	N

[1] Furunculosis incidence in moribund fish removed from groups fed WV1, WV2, OMP (80%) and OMP (65%) was respectively 4/6, 6/6, 0/4, and 5/5.

[2] Groups fed WV1, WV2 and OMP (80%) had high hepatic and omentum lipid deposition (HL). The liver and omentum in coho fed OMP (65%) and in wild smolts contained respectively a low level of lipid (LL) or almost no lipid (VLL).

[3] Normal structure.

TABLE 9 (cont)

[4] In all groups, ova were in the late perinucleolar stage (LPS) and measured 180-270 μ.

[5] Histological criteria indicated high thyroid activity in all groups. Thyroid follicle epithelial cell heights in most fish examined ranged between 4.5 and 6.5 μ. Readsorption vacuoles were common and a few mitotic figures were noted in each follicle.

[6] In all groups pituitary cytology was typical of healthy smolts. Large, well granulated somatotrops were the dominant cell type.

TABLE 10 - Plasma sodium titres ($\bar{X}$ ± 2SEM) in juvenile coho 24 hr after transfer to 10°C seawater (salinity 29-30‰). Osmoregulatory challenge test was conducted on May 4, 1979. Numbers of fish sampled are indicated in brackets.

Diet	Mortality 24 hr after SW transfer	Weight	Plasma sodium (meq/l)[1]
WV1	0/16	19.0 ± 1.6	157.1 ± 5.6 (12)
WV2	0/15	20.6 ± 2.8	159.4 ± 5.2 (12)
OMP (80%)	0/16	18.3 ± 3.4	156.2 ± 7.2 (12)
OMP (65%)	0/16	18.2 ± 1.8	160.9 ± 4.2 (12)

[1] ANOVA indicated no significant differences between groups ($P > 0.05$).

TABLE 11 - Estimated returns of 2, 3 and 4 year-old cultured 1977 brood Quinsam hatchery coho. Estimated percent returns are shown for the commercial and recreational fisheries, hatchery and overall. Cultured fish received experimental diets or OMP during freshwater residency.

		Treatment				
		WV1	WV2	OMP (80%)	OMP (65%)	Quinsam production
Tag code		02-1746	02-1747	02-1748	02-1749	02-1733
No. of fish released-total		78,480	100,067	84,318	84,346	984,026
-tagged		25,397	25,222	25,841	23,245	68,581
Release date		04/05/79	04/05/79	04/05/79	04/05/79	04/05/79
Mean wt at release (g)		20.20	20.00	20.80	19.20	20.30
Commercial fishery returns						
Canadian	(1979)	4	10	5	4	18
	(1980)	1150	1143	1237	1186	2805
	(1981)	0	0	0	0	0
United States	(1979)	0	0	0	0	0
	(1980)	37	55	46	63	83
	(1981)	0	0	6	0	0
Quinsam hatchery returns						
	(1979)	198	318	351	254	662
	(1980)	252	239	250	335	756
	(1981)	0	1	0	0	0
Recreational fishery returns[1]						
	(1979)	12	66	42	6	66
	(1980)	800	829	1200	1236	2211
	(1981)	12	0	0	6	6
Estimated % returns[2]						
- commercial fishery		4.7	4.8	5.0	5.4	4.2
- hatchery		1.8	2.2	2.3	2.5	2.1
- recreational fishery		3.2	3.5	4.8	5.4	3.3
- total		9.7	10.6	12.1	13.3	9.6

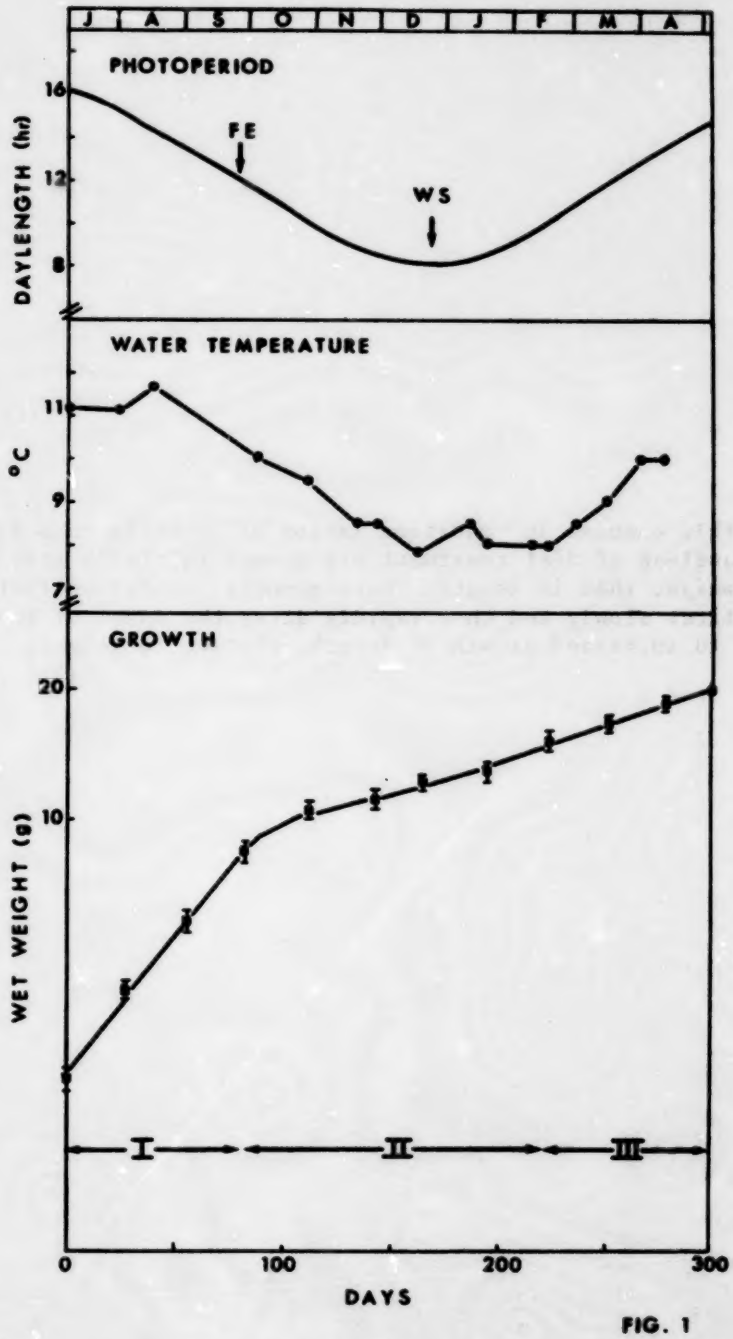
TABLE 11 (cont)

[1] American fishermen accounted for less than 0.15% of the fish caught in the recreational fishery.

[2] Refer to Simpson et al. (1981) and Bailey et al. (1983a,b) for detailed return information. Return data for Alaskan and Washington State fisheries were obtained from Karen Crandall and Dick O'Connor, respectively.

Figures

Fig. 1 - Patterns for daylength, water temperature and growth of juvenile coho (semilogarithmic plot of mean weights for coho fed WV1 shown) during the study period. Three periods of exponential growth or growth stanzas (I, II and III) were observed for all groups. Cessation of the initial rapid period of growth corresponded closely to the fall equinox (FE). Stanza III began after the winter solstice (WS) when both daylength and water temperatures were increasing.


J
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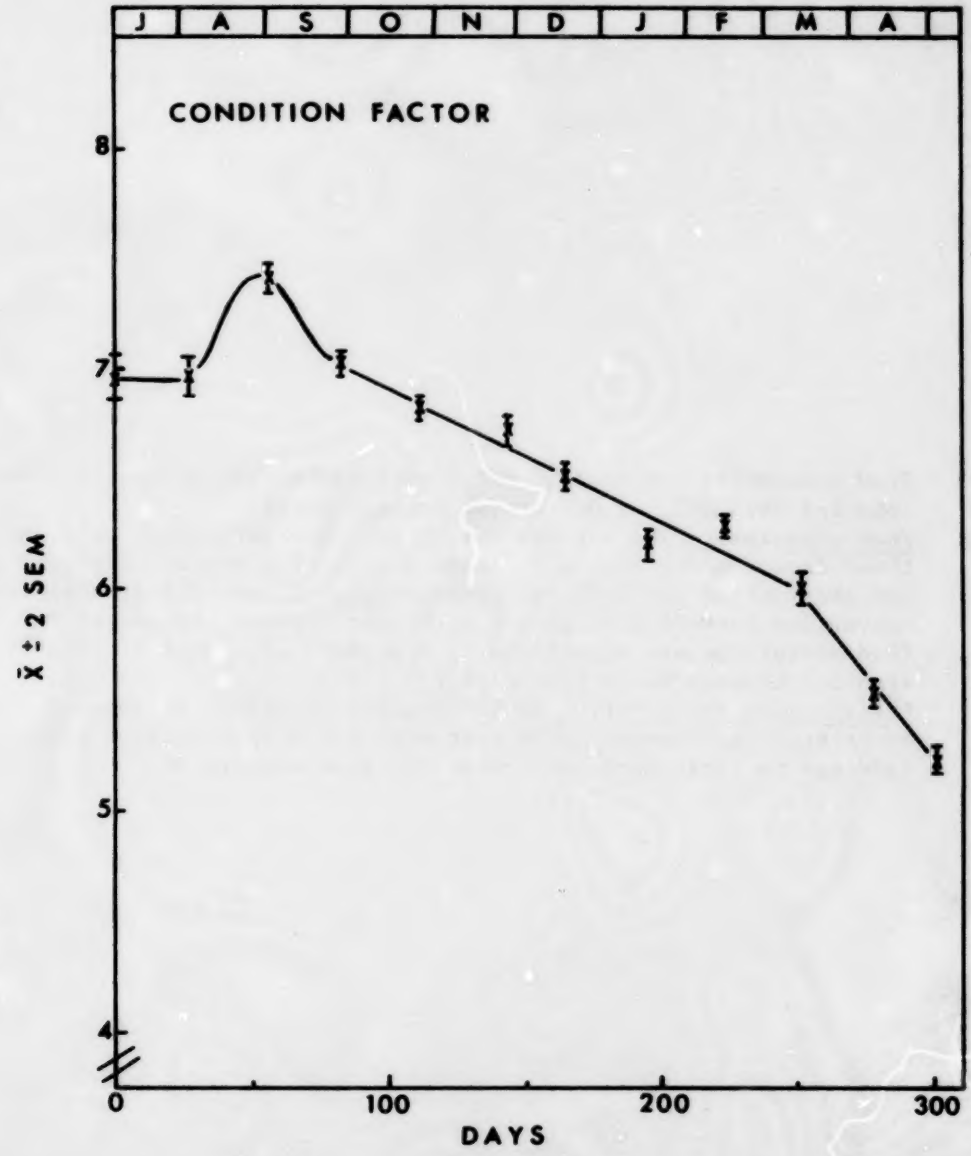
PHOTOPERIOD
DAYLENGTH (hr)
16
12
8
FE
WS
WATER TEMPERATURE
°C
11
9
7
GROWTH
WET WEIGHT (g)
20
10
I
II
III
0
100
200
300
DAYS

FIG. 1

Fig. 2 - Monthly changes in condition factor of juvenile coho fed WV1. Regardless of diet treatment all groups initially grew more rapidly in weight than in length. Subsequently, condition factors declined at first slowly and then rapidly after the onset of smoltification due to increased growth in length relative to weight.


J
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CONDITION FACTOR
8
7
6
5
4
$\bar{X} \pm 2$ SEM
0
100
200
300
DAYS

FIG. 2

Fig. 3 - Food conversion and protein efficiency ratios for groups of juvenile coho fed WV1, WV2, or OMP at two ration levels.
Food conversion: Two-way ANOVA with one observation per cell and a three factor ANOVA with diet crossed with time nested in stanza and one observation per cell indicated no significant differences in food conversion between diet groups within or between stanzas ($P > 0.05$). Food conversion was significantly depressed in stanza II relative to stanza I (Newman-Keuls test with $P = 0.05$).
Protein efficiency ratio: ANOVA (designs identical to those for food conversion) and Newman-Keuls test with $P = 0.05$ indicated identical findings to those mentioned above for food conversion.

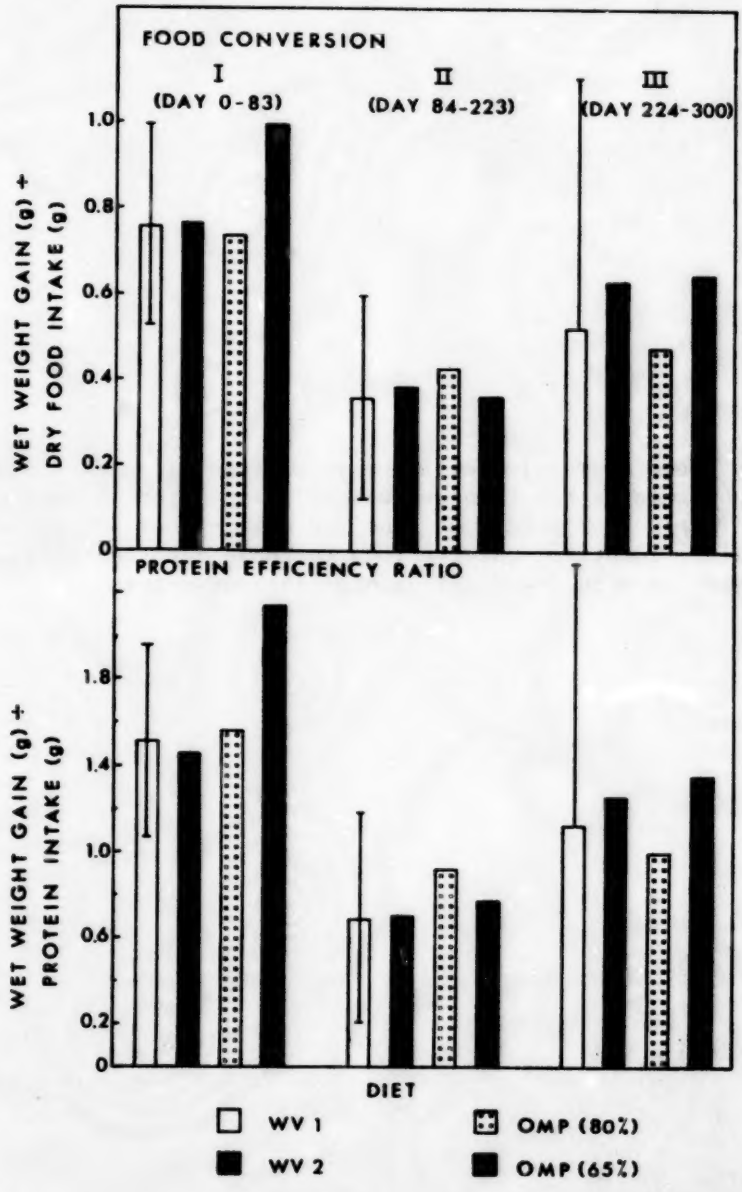

FOOD CONVERSION
I
(DAY 0-83)
II
(DAY 84-223)
III
(DAY 224-300)
WET WEIGHT GAIN (g) ÷
DRY FOOD INTAKE (g)
1.0
0.8
0.6
0.4
0.2
0
PROTEIN EFFICIENCY RATIO
WET WEIGHT GAIN (g) ÷
PROTEIN INTAKE (g)
1.8
1.4
1.0
0.6
0.2
0
DIET
WV 1
WV 2
OMP (80%)
OMP (65%)

FIG. 3

Fig. 4 - Gross food conversion efficiency, protein efficiency ratio (dry weight gain rather than wet weight gain ÷ protein intake) and protein utilization for groups of coho fed WV1, WV2 or OMP at two ration levels. Identical observations to those reported in Fig. 3 for food conversion were found for each of the parameters.

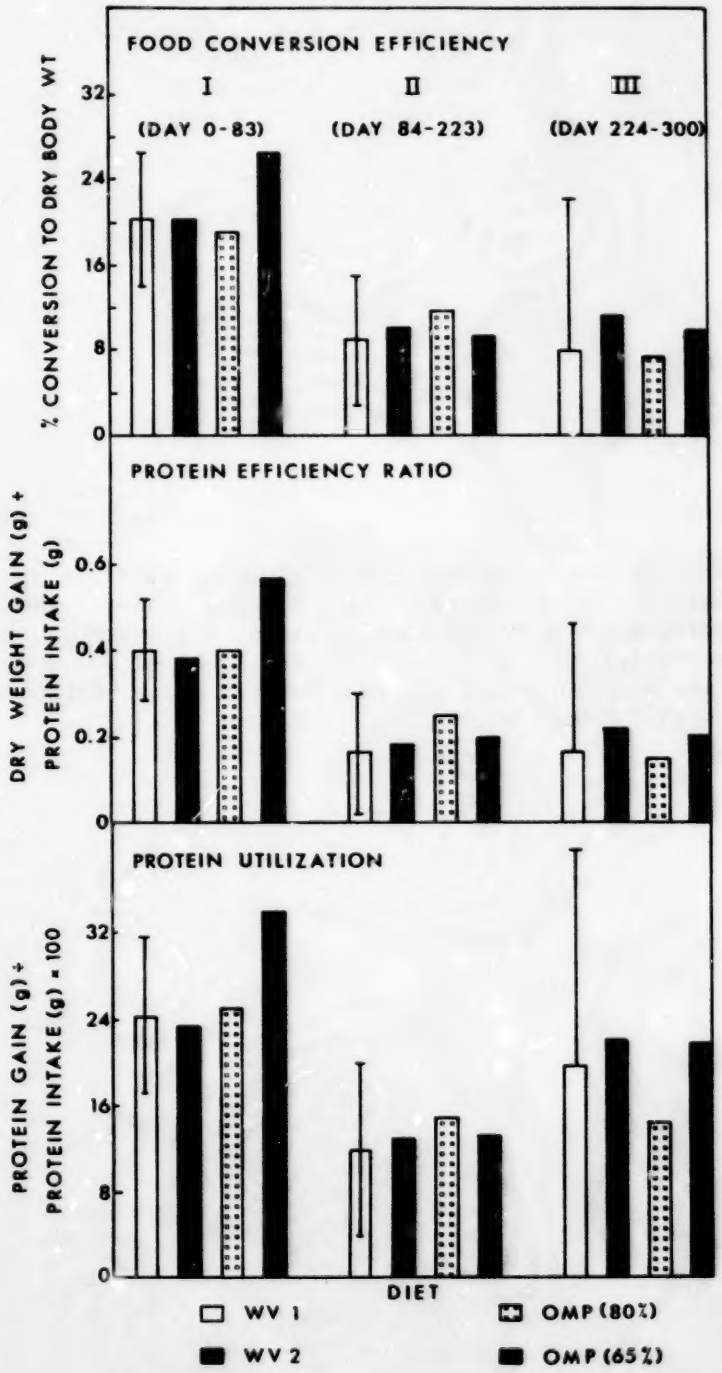

FOOD CONVERSION EFFICIENCY
I
II
III
(DAY 0-83)
(DAY 84-223)
(DAY 224-300)
% CONVERSION TO DRY BODY WT
32
24
16
8
0
PROTEIN EFFICIENCY RATIO
DRY WEIGHT GAIN (g) ÷ PROTEIN INTAKE (g)
0.6
0.4
0.2
0
PROTEIN UTILIZATION
PROTEIN GAIN (g) ÷ PROTEIN INTAKE (g) × 100
32
24
16
8
0
DIET
WV 1
WV 2
OMP (80%)
OMP (65%)

FIG. 4

Fig. 5 - Final whole body proximate compositions of wild and of cultured coho fed WV1, WV2 or OMP at two ration levels. One-way ANOVA of group percentages for body moisture, protein, lipid and ash indicated respectively, $P < 0.05$, $P < 0.01$, $P < 0.01$ and $P > 0.05$. Diet groups with the same superscript form a homogeneous subset (Newman Keuls test with $P = 0.05$).

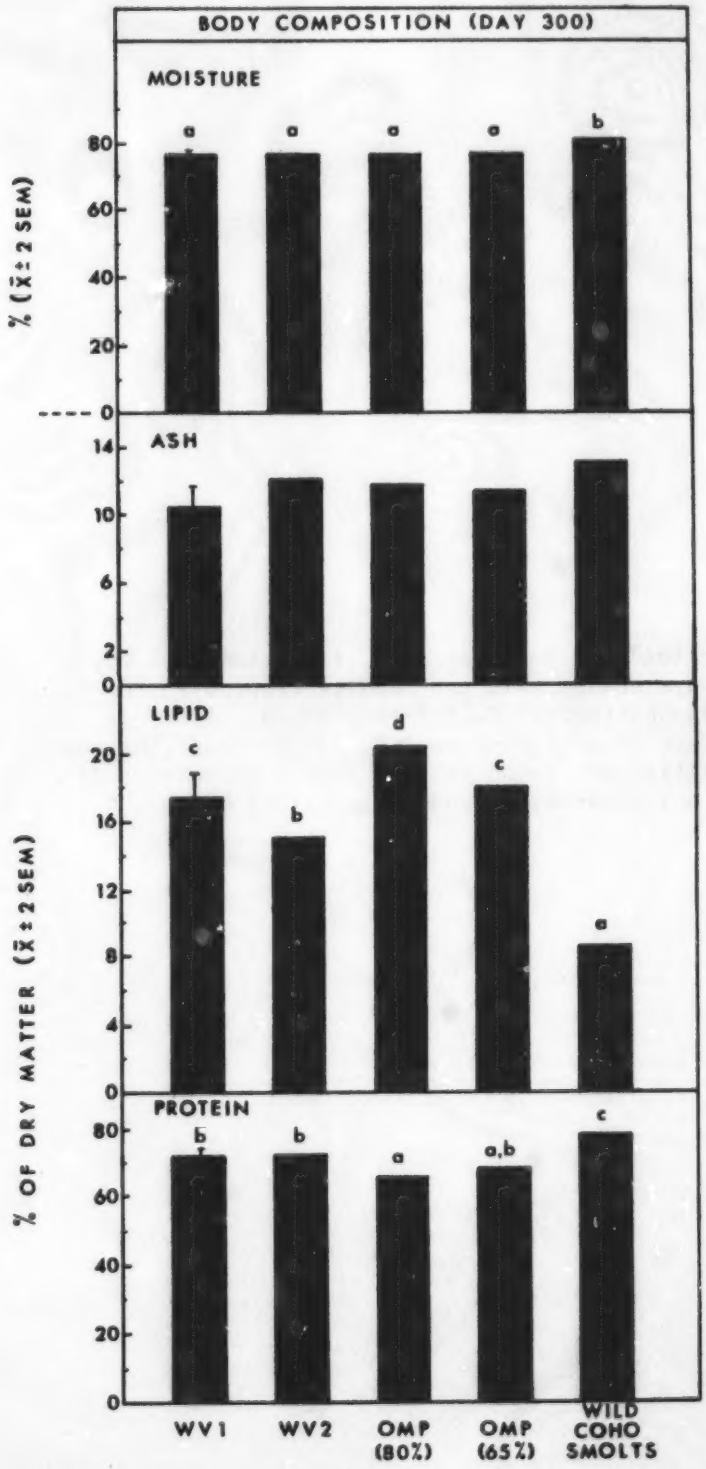
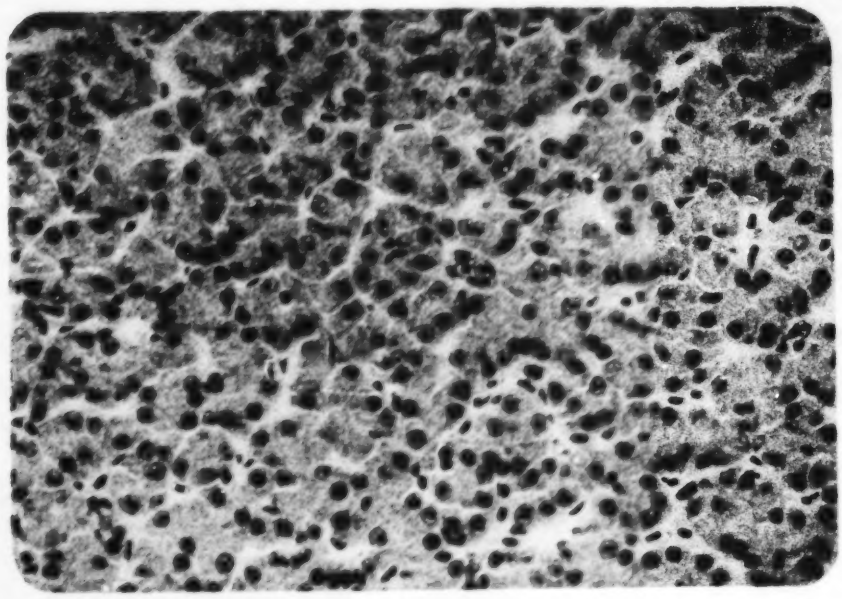
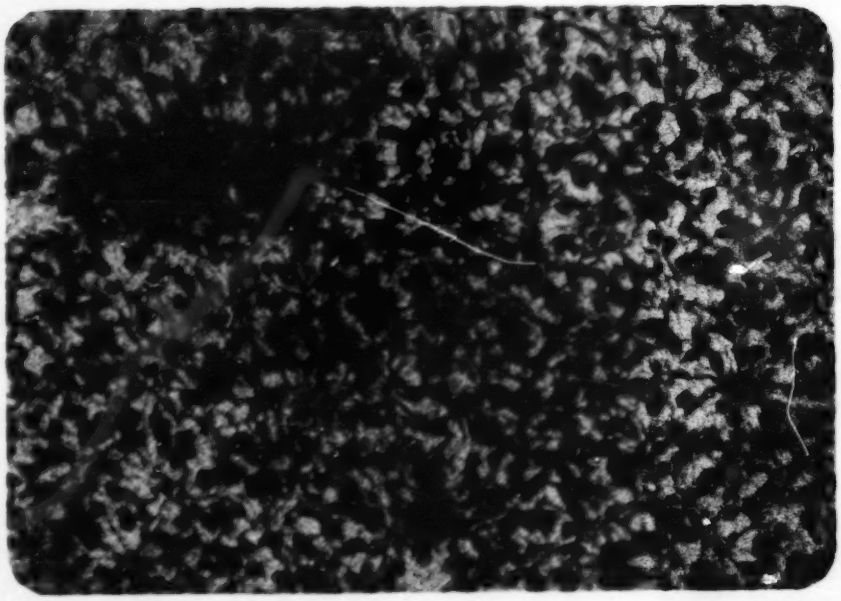

BODY COMPOSITION (DAY 300)
MOISTURE
ASH
LIPID
PROTEIN
% (X̄ ± 2 SEM)
% OF DRY MATTER (X̄ ± 2 SEM)
WV1
WV2
OMP (80%)
OMP (65%)
WILD COHO SMOLTS
DIET

FIG. 5

Fig. 6 - Liver (6A) and pancreas (6B) structure of cultured coho fed OMP for 300 days and of wild coho smolts trapped in the immediate vicinity of Quinsam hatchery. Note little if any, lipid in the liver and pancreas of wild coho smolts. By contrast, extensive lipid deposition was found in the liver and pancreas of coho fed OMP. All sections hematoxylin and eosin (liver 80 to 100 x; pancreas x 40).



WILD



CULTURED

FIG. 6A

WILD

CULTURED

FIG. 6B